# Carbon Management Program

**Presented to:**
Georgia Institute of Technology

GT Clean Energy Speakers Series
Atlanta, GA
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**Presented by:**
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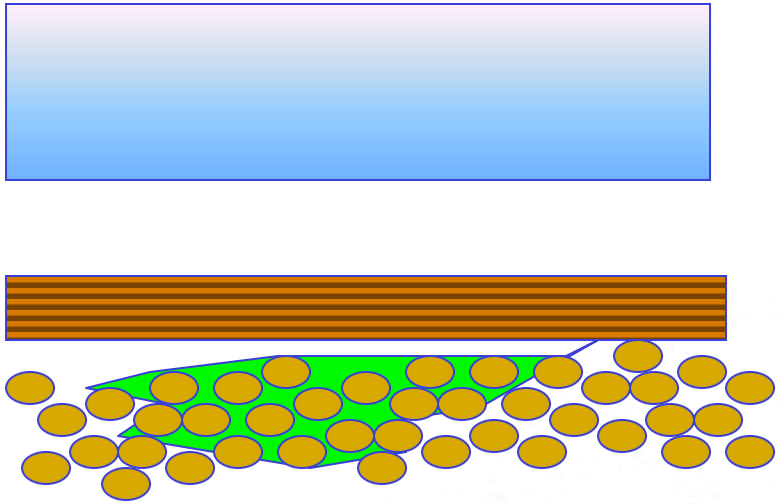
Senior Technical Advisor
Southern States Energy Board

# What is Carbon Capture & Sequestration?

- Carbon sequestration is the capture and storage of carbon dioxide and other greenhouse gases that would otherwise be emitted into the atmosphere.
- Greenhouse gases can be captured at the point of emission, or they can be removed from the air.
- Captured gases can be:
  - stored, or *sequestered,* in *underground reservoirs,*
  - dissolved in deep oceans,
  - converted to rock-like solid materials, or
  - absorbed by trees, grasses, soils, or algae.

*(National Energy Technology Laboratory, U.S. Department of Energy)*

# Most Suitable Geologic Locations



Identify a porous and permeable rock volume in the subsurface

…That is below underground sources of drinking water

…and isolated from them and from escape to the atmosphere by one or more seals.

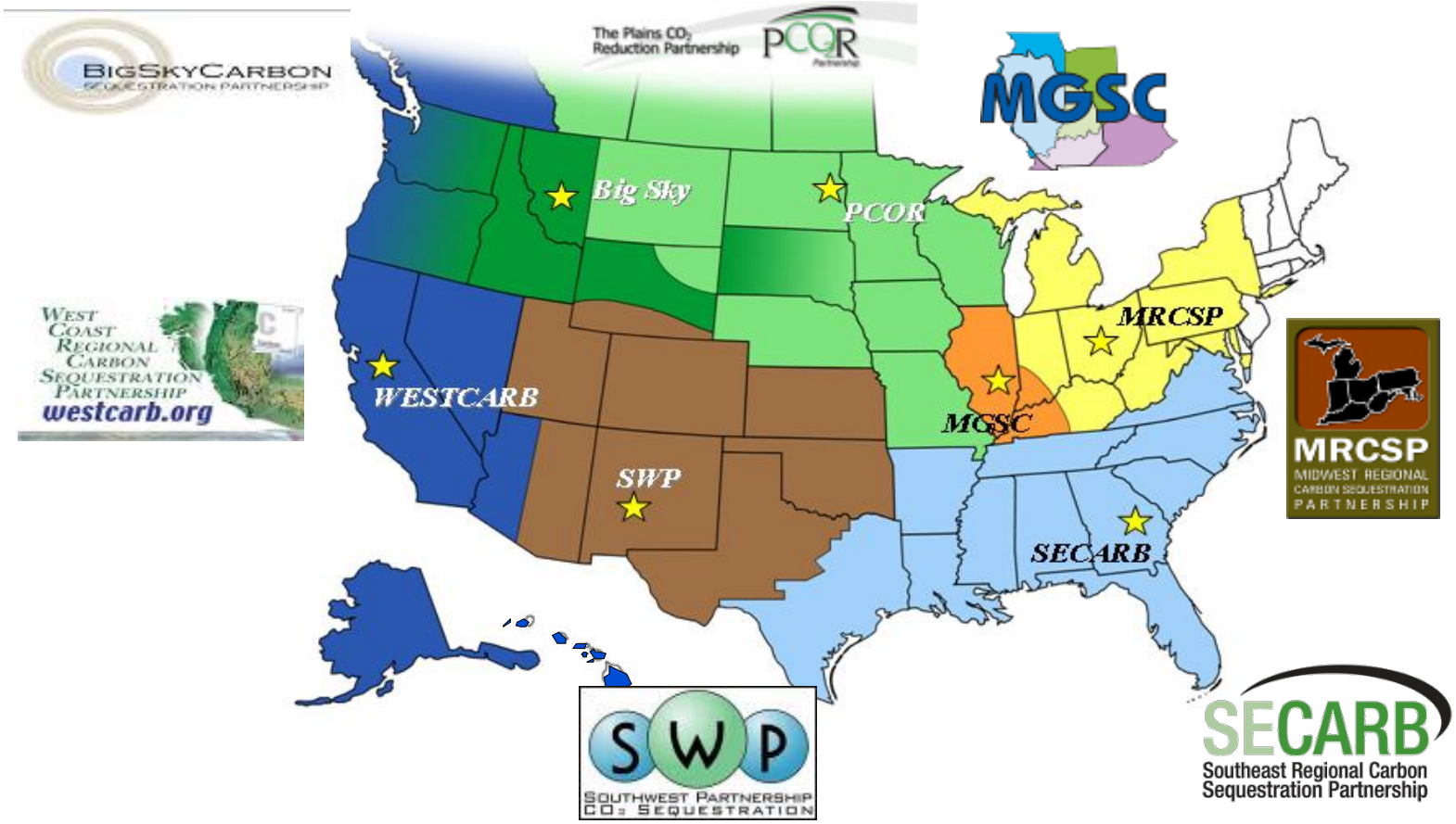
Collect data on areal extent, thickness, $CO_2$ density, porosity, and permeability that permit simple estimates of storage capacity for $CO_2$.

If preceding steps are favorable, proceed to additional steps, including matching to sources, estimating cost, permanence, and risk/uncertainly.

# Regional Carbon Sequestration Partnerships

*"Developing the Infrastructure for Wide Scale Deployment"*

**7 Partnerships, 500+ distinct organizations, 43 States, 4 Canadian Provinces**



# Regional Carbon Sequestration Partnerships

| | |
|---|---|
| West Coast Regional Carbon Sequestration Partnership westcarb.org | **California Energy Commission** http://www.westcarb.org/ |
| Southwest Regional Partnership on Carbon Sequestration | **New Mexico Institute of Mining and Technology** http://www.southwestcarbonpartnership.org/ |
| BIGSKYCARBON SEQUESTRATION PARTNERSHIP | **Montana State University** http://www.bigskyco2.org/ |
| Plains $CO_2$ Reduction Partnership | **University of North Dakota, Energy & Environmental Research Center** http://www.undeerc.org/pcor/ |
| MGSC | **University of Illinois, Illinois State Geological Survey** http://www.sequestration.org/ |
| MRCSP MIDWEST REGIONAL CARBON SEQUESTRATION PARTNERSHIP | **Battelle Memorial Institute** http://www.mrcsp.org/ |
| SECARB Southeast Regional Carbon Sequestration Partnership | **Southern States Energy Board** http://www.secarbon.org/ |

## Characterization – Phase I

- 24 months (2003-2005)
- 7 Partnerships (41 states)
- $16M DOE funds

## Validation – Phase II

- 4 years (2005 - 2010)
- Field validation tests
  - Over 20 Geologic
  - 11 Terrestrial
- $112M DOE funds
- $43M cost share

## Deployment - Phase III

- 10 years (2007-2017)
- Seven large volume injection tests
- Over $700M DOE and cost share

# CCS Best Practice Manuals

## *Critical Requirement For Significant Wide Scale Deployment -Capturing Lessons Learned*

| Best Practices Manual | Version 1 (Phase II) | Version 2 (Phase III) | Final Guidelines (Post Injection) |
|---|---|---|---|
| Monitoring, Verification and Accounting | 2009 | 2017 | 2020 |
| Site Characterization | 2010 | 2016 | 2020 |
| Simulation and Risk Assessment | 2010 | 2017 | 2020 |
| Well Construction and Closure | 2010 | 2017 | 2020 |
| Regulatory Compliance | 2010 | 2016 | 2020 |
| Public Outreach and Education | 2009 | 2016 | 2020 |
| Terrestrial | 2010 | **2016 – Post MVA Phase III** | |

# SECARB

## Southeast Regional Carbon Sequestration Partnership



# Acknowledgements


- This material is based upon work supported by the U.S. Department of Energy National Energy Technology Laboratory.

- Cost share and research support provided by SECARB/SSEB Carbon Management Partners

# SECARB Cost-sharing Partners


SECARB
Southeast Regional Carbon Sequestration Partnership

- Advanced Resources International
- Alpha Natural Resources
- Amvest Gas Resources, Inc.
- AMVEST Oil & Gas
- Arch Coal
- August Systems, Inc.
- Bright Energy, Inc.
- CDX Gas, LLC
- Consol Energy
- Dart Energy Corporation
- Dart Oil & Gas
- Denbury Resources, Inc.
- Dominion
- Eastern Coal Council
- ***Electric Power Research Institute***
- Equitable Production Company
- F.D. Robertson
- ***Geological Survey of Alabama***
- GeoMet
- Interstate Oil & Gas Compact Commission
- Kentucky Energy & Environment Cabinet, Division of Energy Development and Independence
- Marshall Miller & Associates
- Massachusetts Institute of Technology
- McJunkin Appalachian Oil Field Supply Company
- Mississippi State University (Institute for Clean Energy Technology)
- Natural Resource Partners
- PennVirginia Operating Company LLC
- PennVirginia Resources
- Petron Resources
- Piney Land Company
- Pocahontas Land Corporation
- Praxair
- RMB Earth Science Consultants, Ltd.
- Schlumberger
- Smith Energy
- Southern Company
- ***Southern States Energy Board (Lead)***
- TECO Coal Corporation
- University of Alabama
- University of Kentucky (Kentucky Geological Survey)
- ***University of Texas, Bureau of Economic Geology***
- ***Virginia Tech, Virginia Center for Coal and Energy Research***
- West Virginia University

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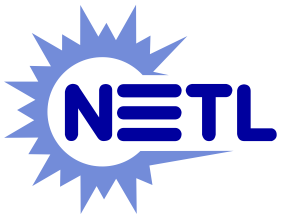
***Green text indicates local field test site team lead***

# SECARB Program



**Phase I – Regional Characterization and Selection of Most Promising Field Demonstrations (2003-2005)**

- General Characterization of Regional Geologic and Terrestrial Sequestration Options
- Nomination of 4 Phase II Small-Scale Geologic Sequestration Projects

**Phase II – Small-Scale $CO_2$ Injection Demonstrations (2005-2010)**

- Continued Characterization of Regional Geology
- Two Coal Seam Projects
- Two Saline Tests

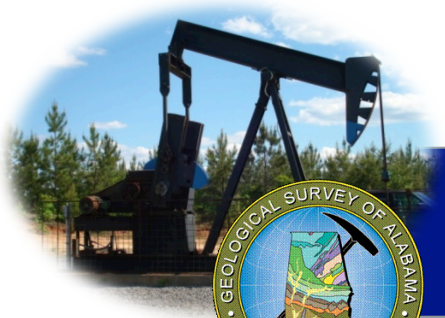
**Phase III - Large-Scale $CO_2$ Injections (2007-2017)**

- "Early" Test – monitoring large volume $CO_2$ injection
- "Anthropogenic" Test – integrated $CO_2$ capture, transportation and geologic storage

# SECARB Phase II

VirginiaTech
Invent the Future

**Coal Seam Project**
Host Company: CNX Gas
Russell County, Virginia




**Coal Seam Project**
Host Company: El Paso E&P
near Tuscaloosa, Alabama

**Characterization for Large-Volume $CO_2$ Storage Options**

MARSHALL MILLER & ASSOCIATES®

**Stacked Storage Project**
Cranfield Test Site
Host Company: Denbury Resources, Inc.
near Natchez, Mississippi

Gulf Coast Carbon Center

**Mississippi Test Site**
Mississippi Power's Plant Daniel
Escatawpa, Mississippi

EPRI ELECTRIC POWER RESEARCH INSTITUTE

# SECARB Phase II – Virginia

Coal Seam Project - Central Appalachia
Russell County, VA
1,000 tons (January-February 2009)

Well Drilling & Cementing Surface Casing

$CO_2$ Injection Operations

Open House During Injection Operations, February 11, 2009

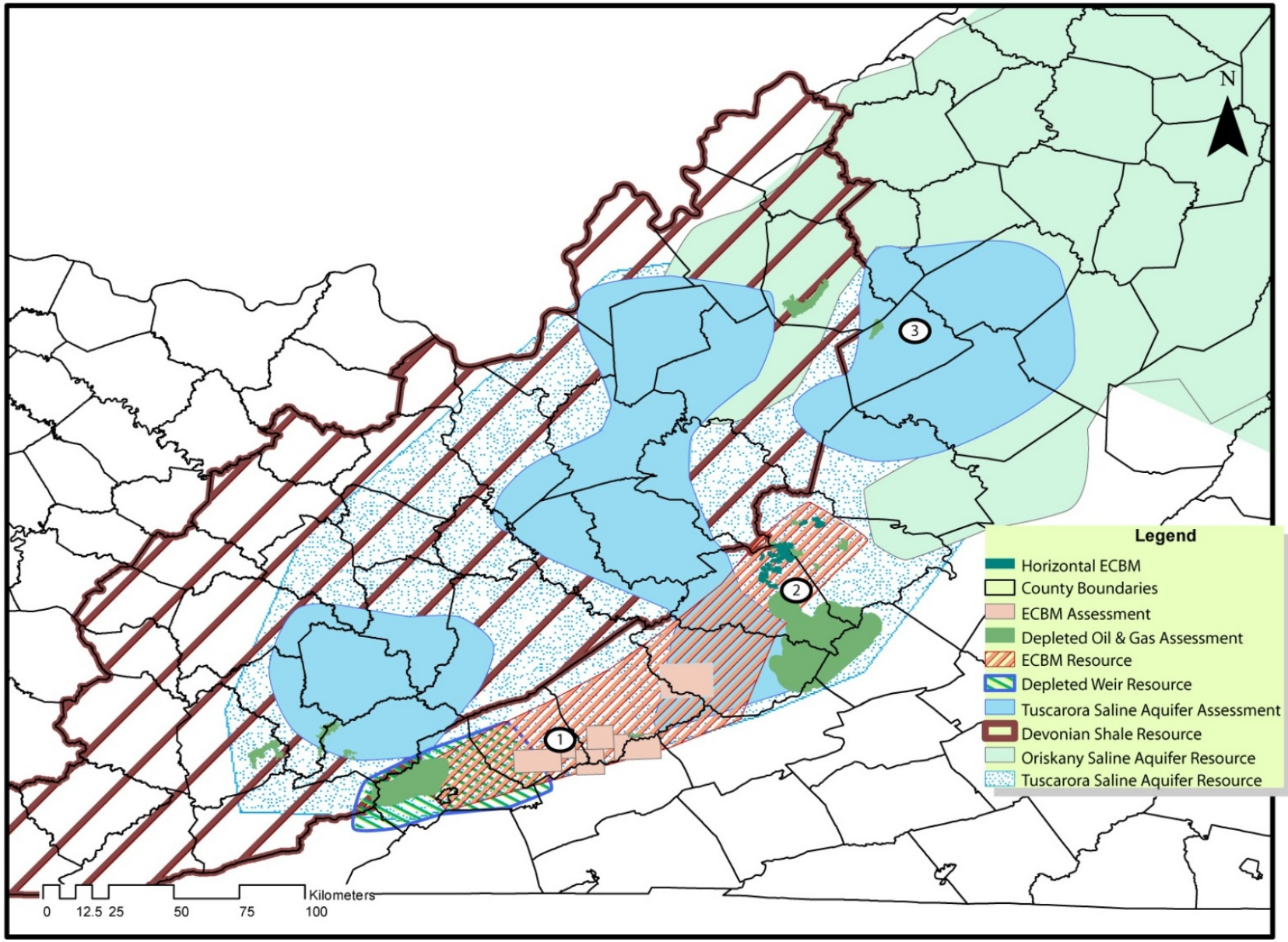
# Large Volume Storage Options for Appalachia

- Characterization of potential large-volume test sites in Central Appalachia for coal seam sequestration and enhanced coalbed methane recovery.
- Design considerations for measurement, monitoring and verification program and site closure.
- Down selection of the most promising test site in Central Appalachia.
- Implementation of public outreach and education.

**Research Partners:**

- Marshall Miller and Associates, Inc.
- Virginia Center for Coal and Energy Research – Virginia Tech (VCCER)
- Geological Survey of Alabama
- Advanced Resources International
- CONSOL Energy
- West Virginia University
- Kentucky Geological Survey

# Prospective Sites and Geologic Options

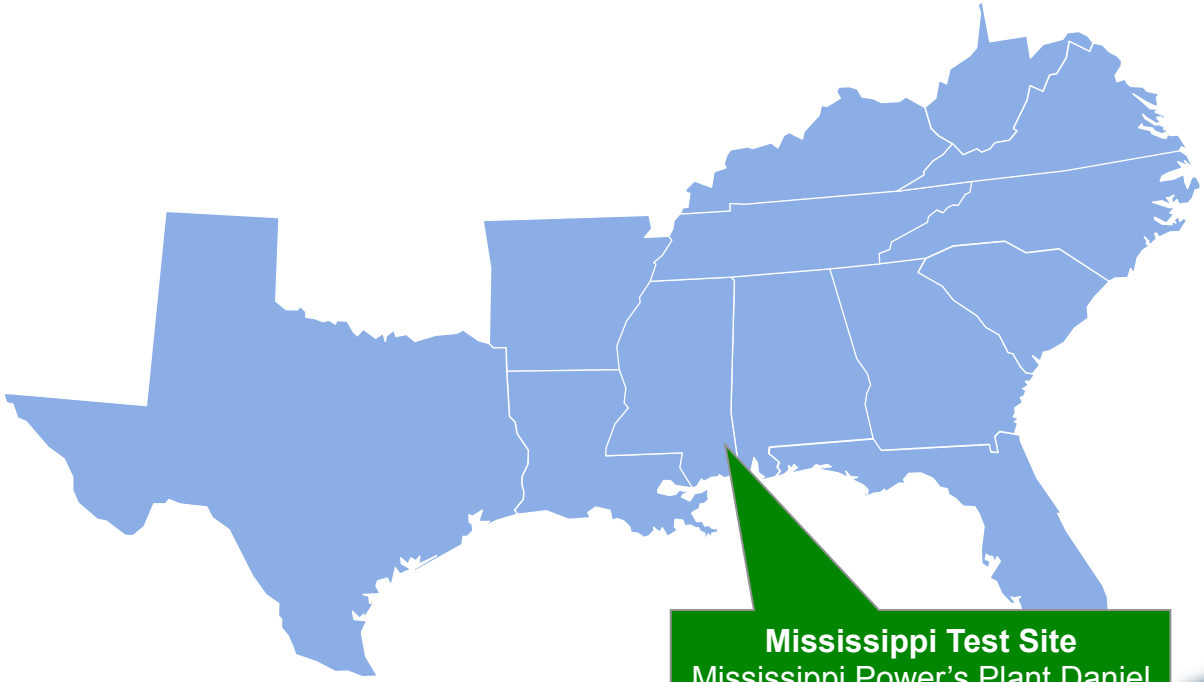


# Findings: Coal Seam Field Tests

- Storage in deep, thin coal seams is a viable option for the Appalachian region
- CO2 readily adsorbs to coal and displaces methane
- Using CO2 for enhanced coalbed methane production is technically feasible but economics must improve
- Reliable monitoring, measurement and verification tools have been demonstrated for coal seam storage

# SECARB Phase II Saline Project

SECARB
Southeast Regional Carbon Sequestration Partnership



**Mississippi Test Site**
Mississippi Power's Plant Daniel
Escatawpa, Mississippi

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# SECARB CO2 Injection Site Design

## Mississippi Power's Plant Victor J. Daniel

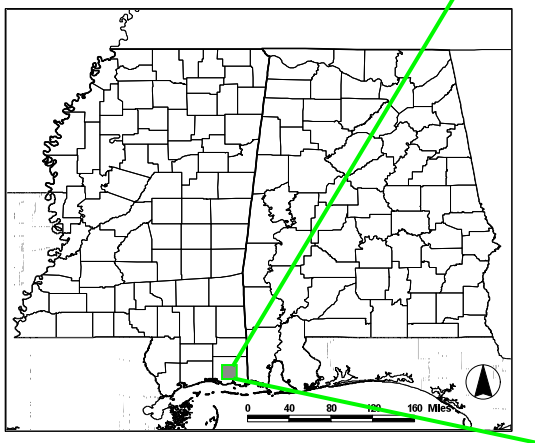



Image Source: Google Earth

# Plant Daniel (Mississippi Power Co)


$CO_2$ Storage Tanks

Plant Daniel Open House During Injection Operations, October 15, 2008

# SECARB Phase III

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**Anthropogenic Test**

Capture: Alabama Power Plant Barry, Bucks, Alabama

Transportation: Denbury Resources

Geo Storage: Denbury's Citronelle Field, Citronelle, Alabama

**Early Test**

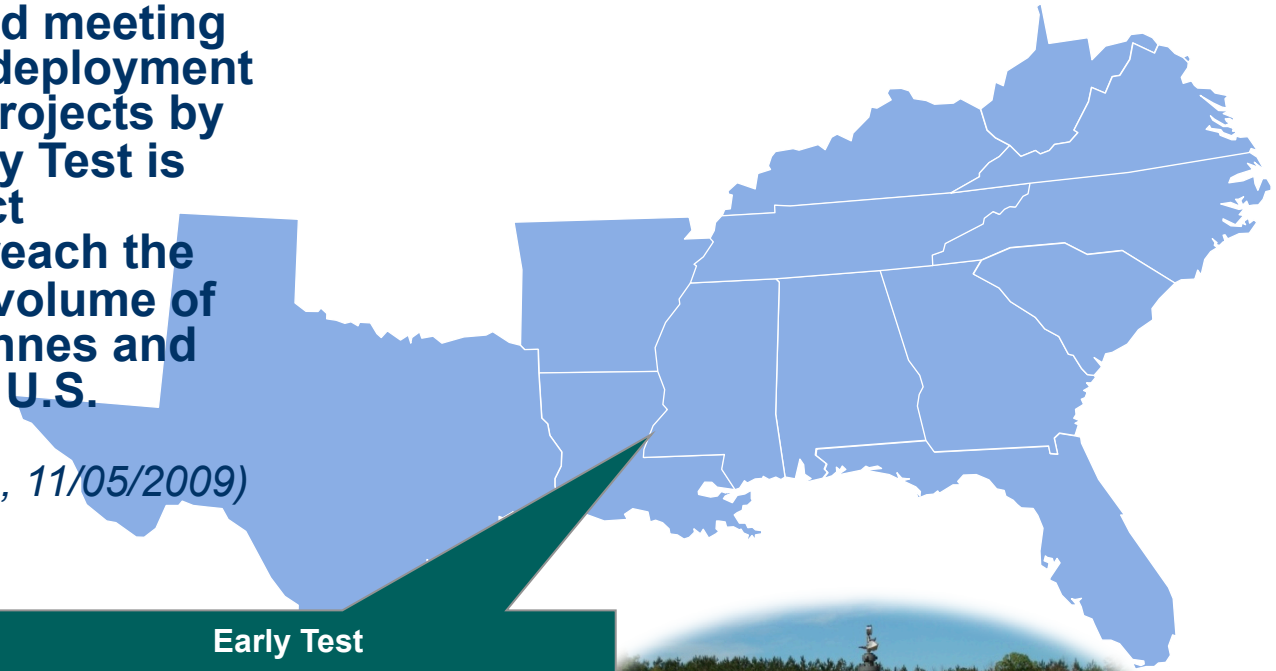
Denbury Resources' Cranfield Field
Near Natchez, Mississippi

Gulf Coast Carbon Center

# SECARB Phase III

**SECARB Early Test was recognized by DOE for furthering CCS technology and meeting G-8 goals for deployment of 20 similar projects by 2020. The Early Test is the fifth project worldwide to reach the $CO_2$ injection volume of one million tonnes and the first in the U.S.**

*- (DOE Techline, 11/05/2009)*



**Early Test**

Denbury Resources' Cranfield Field
Near Natchez, Mississippi

Gulf Coast Carbon Center

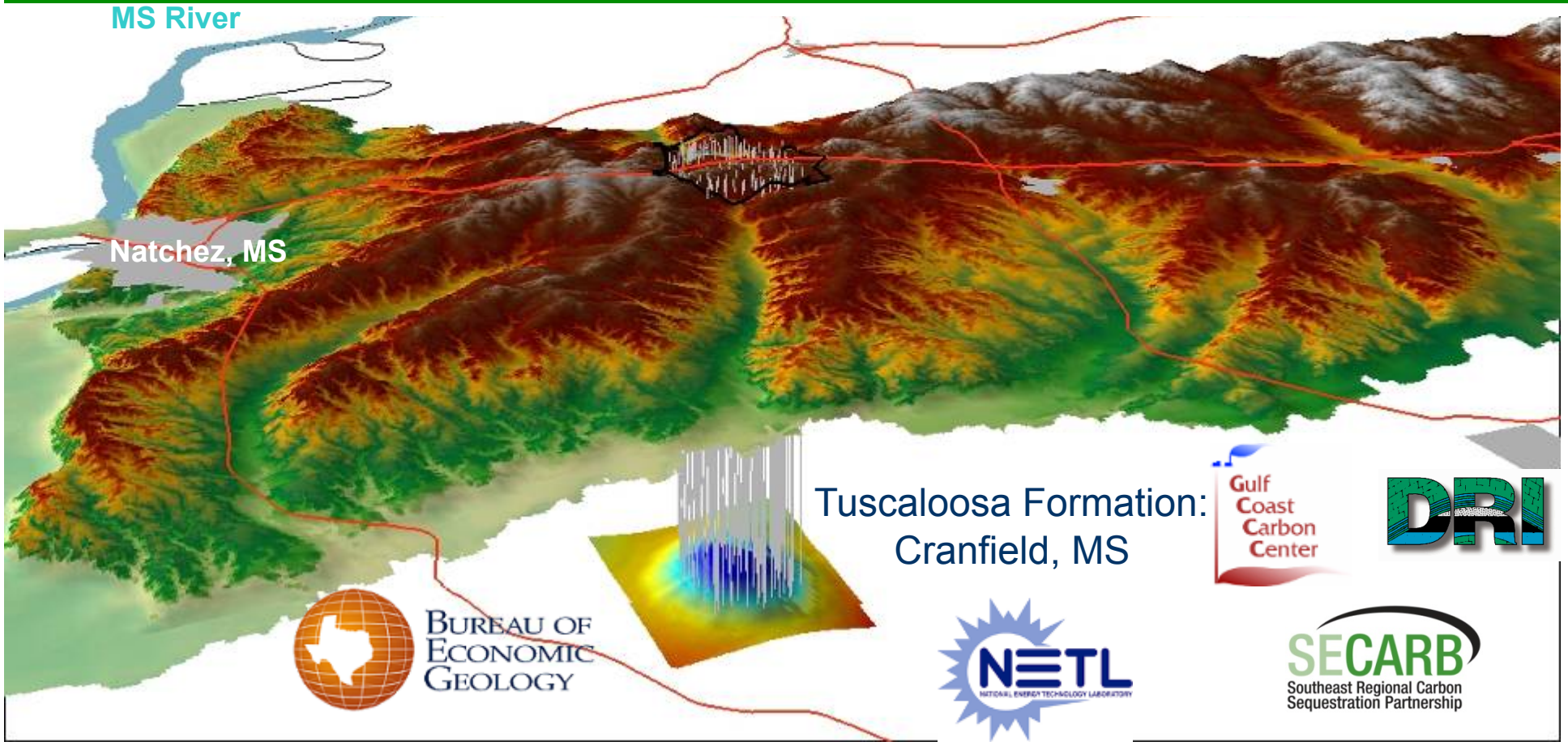
# SECARB Early Large Volume Injection Tests

## Cranfield Unit operated by Denbury Resources Inc

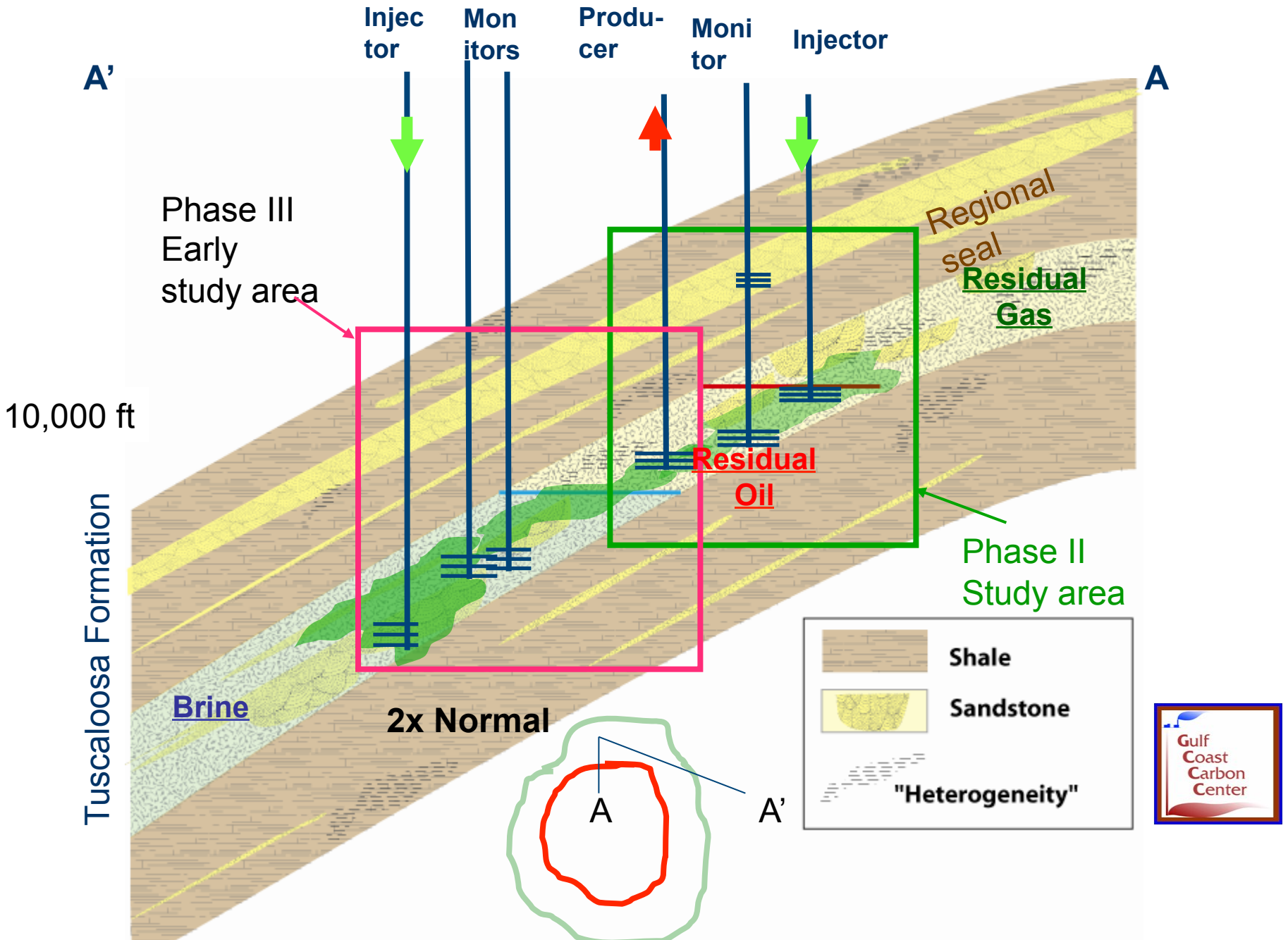
**Depth >10,300 ft**

**Injection Zone – lower Tuscaloosa Formation**

**Injection rate>1 Million tonnes per year**



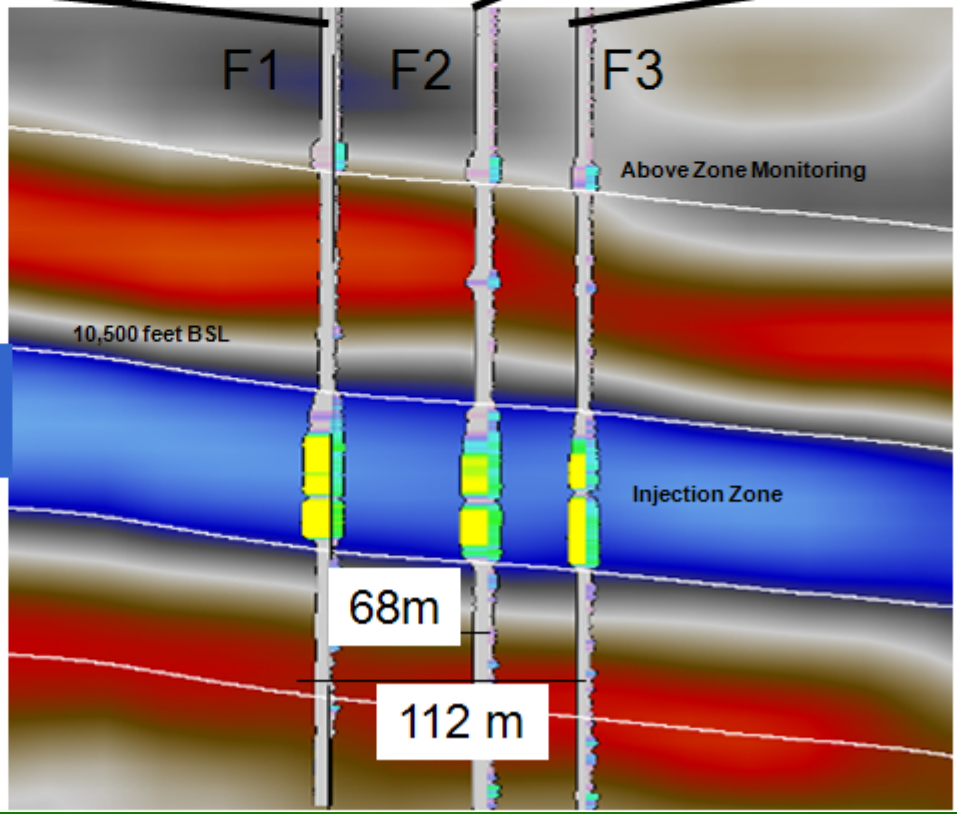
# Cranfield Geometric Overview



# Cranfield Early Test Monitoring: Detailed Area of Study

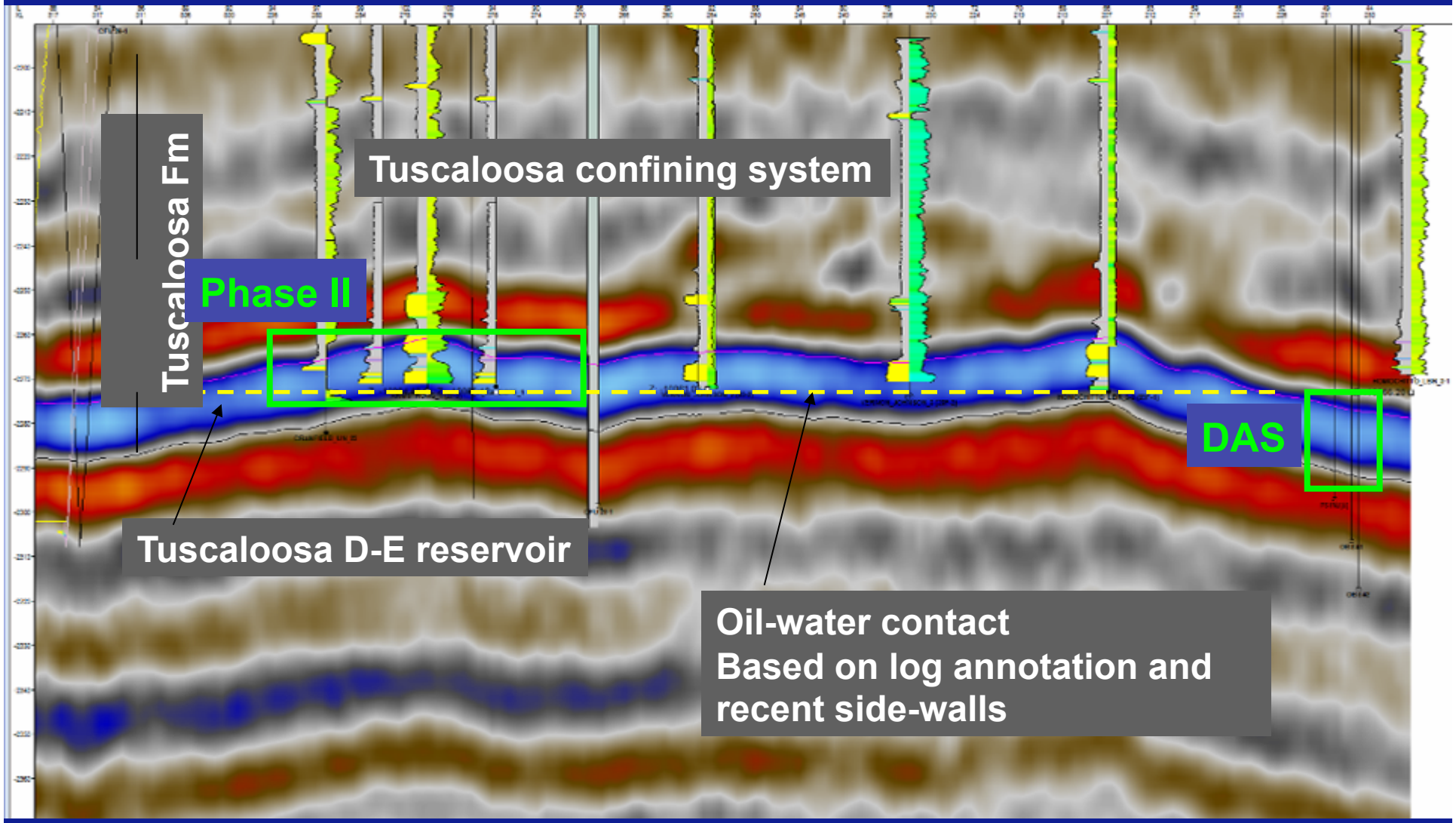

Closely spaced well array to examine flow in complex reservoir

*Lower Tuscaloosa injection zone*




Gulf Coast Carbon Center

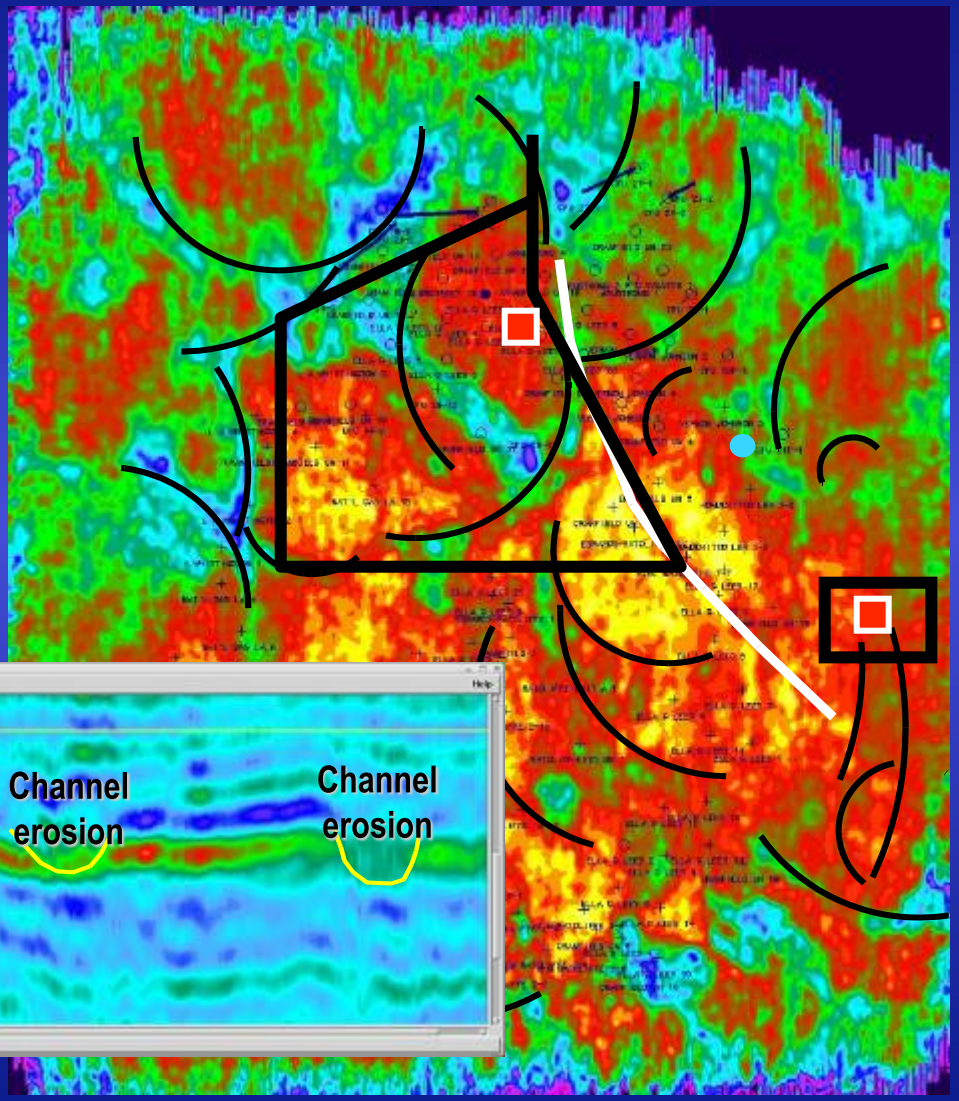
# Characterization of the Reservoir

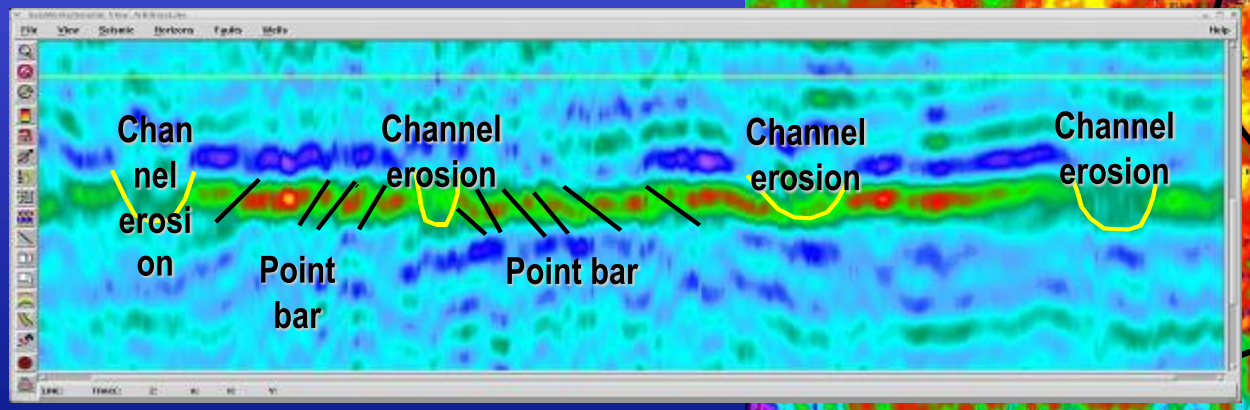



3D Denbury - interpretation Tip Meckel BEG

# Reservoir heterogeneity from surface seismic

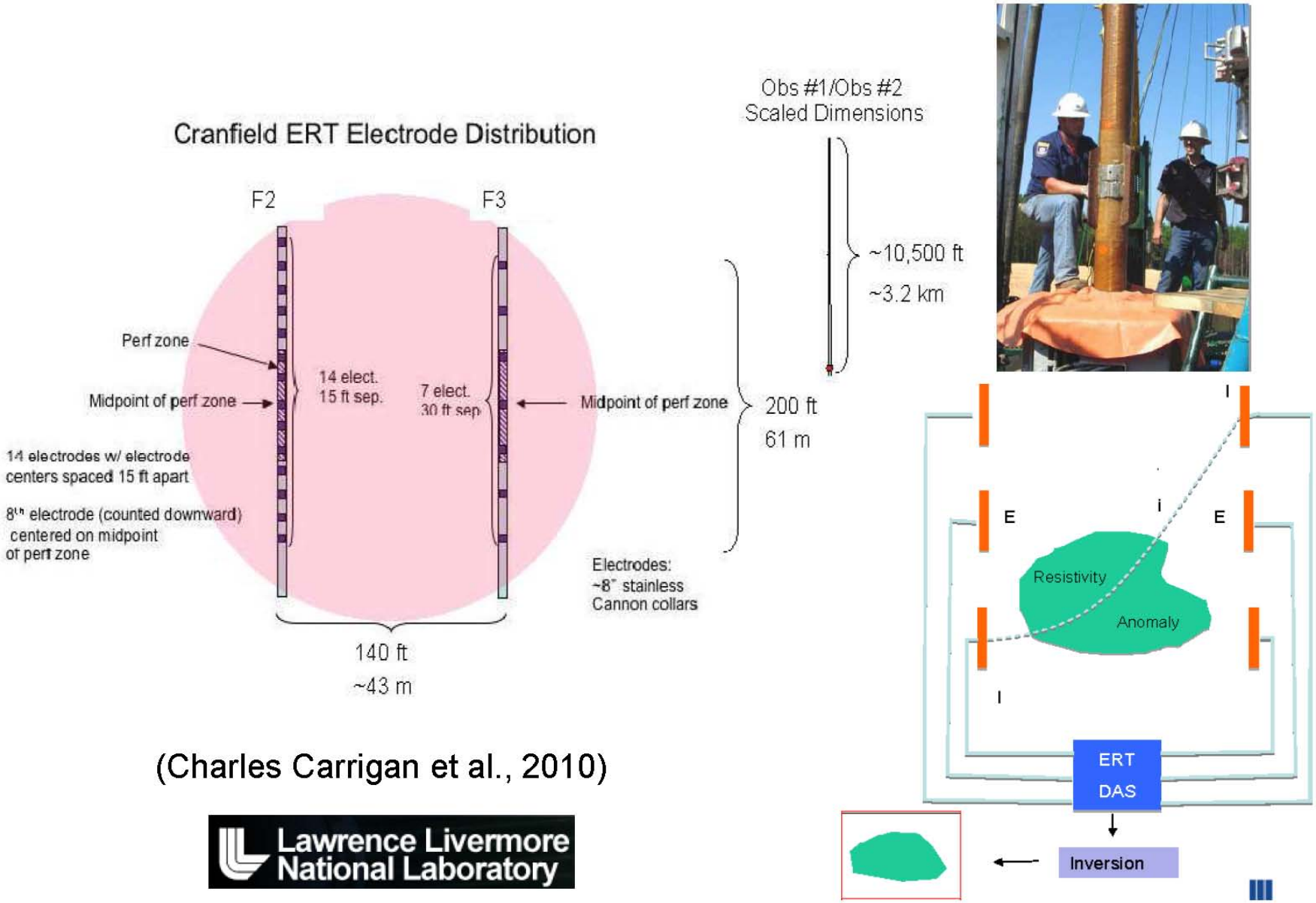
- Stratal slicing for facies
- 90-degree phase
- AVF for thickness/fluid
- AVO for fluid/OWC






Denbury 3-D survey interpretation Hongliu Zeng, BEG

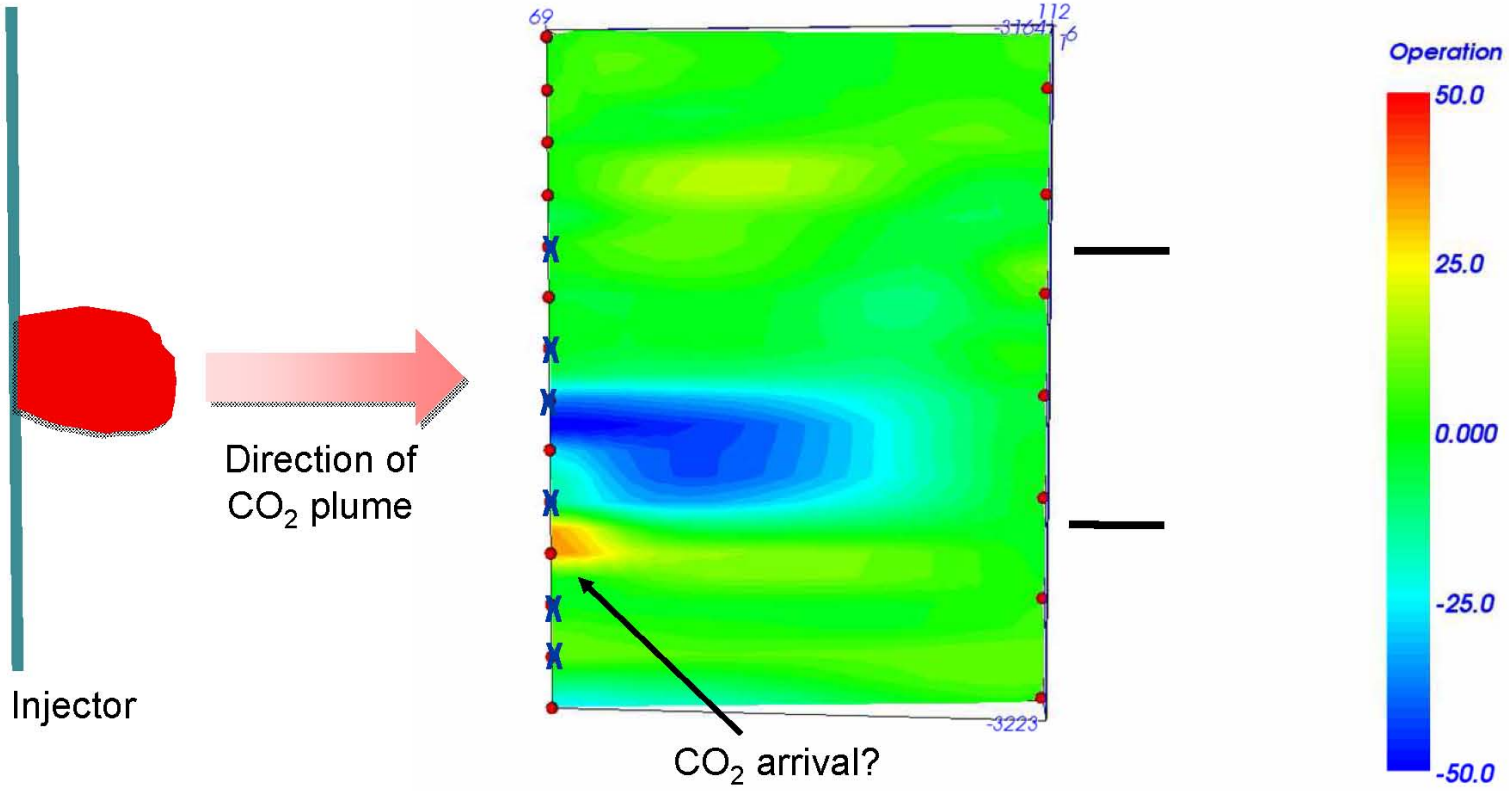
# Crosswell ERT (Electric Resistance Tomography)



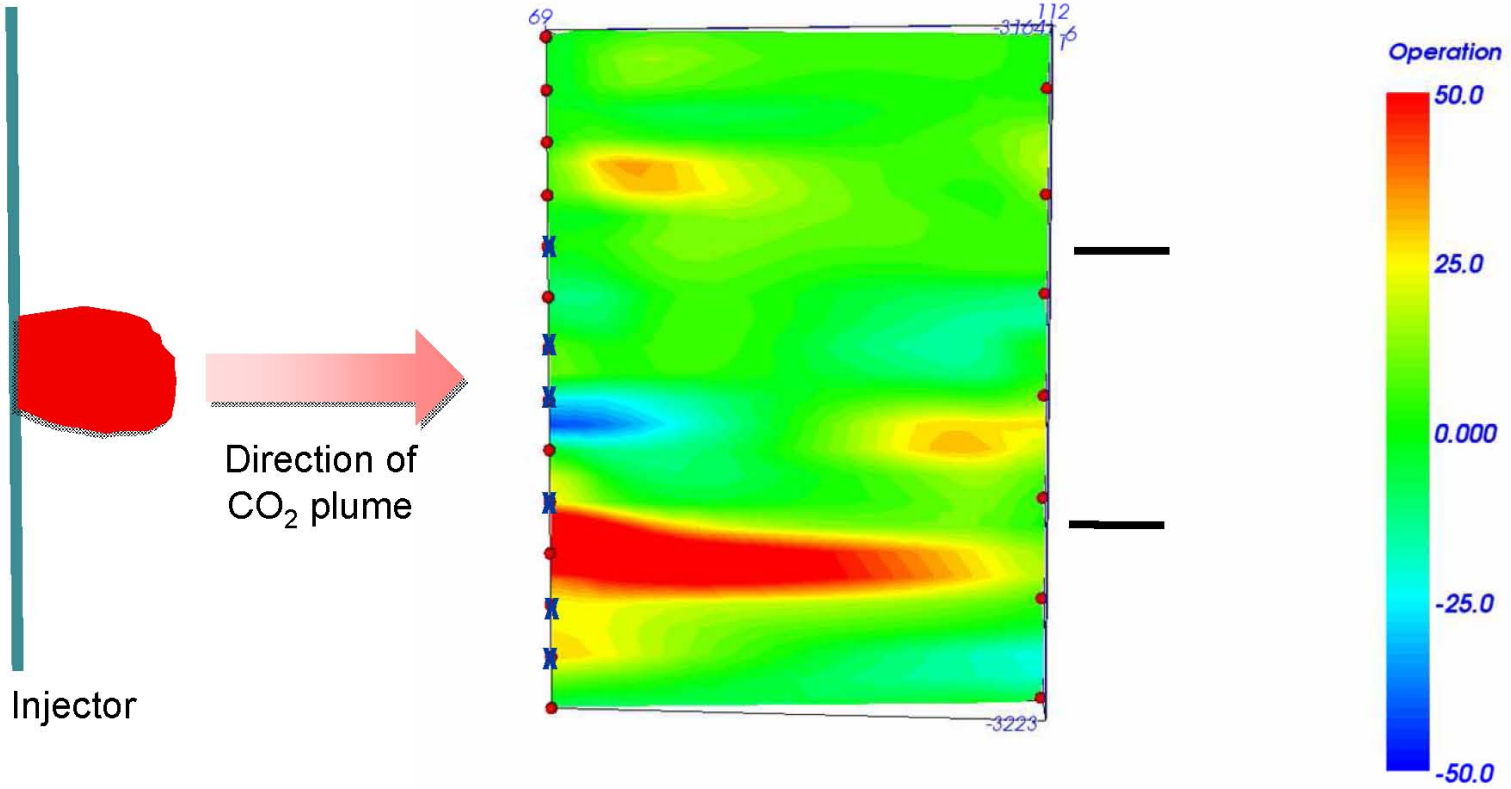

(Charles Carrigan et al., 2010)

Lawrence Livermore National Laboratory

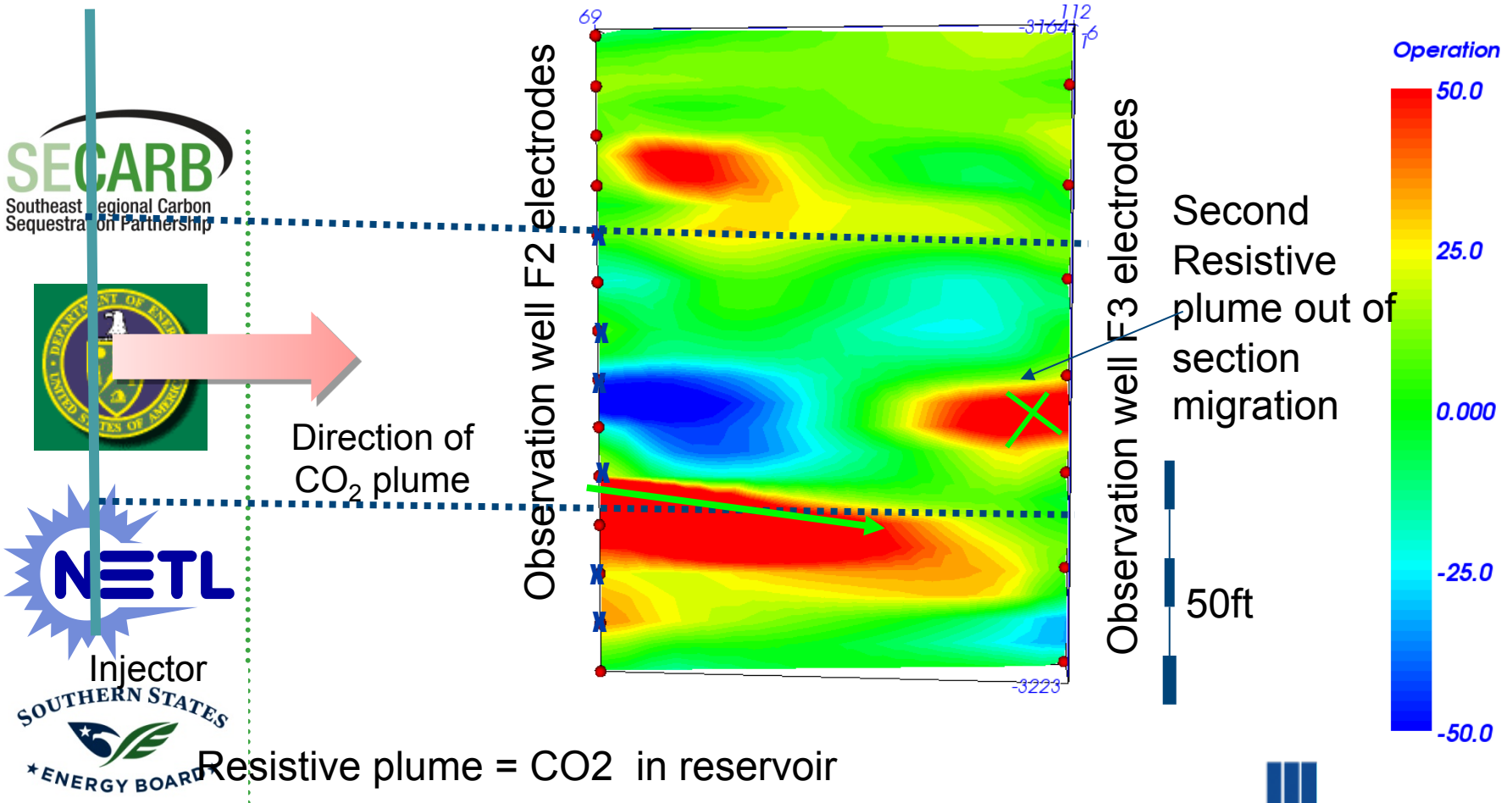
# Arrival of $CO_2$ Plume? (9 Dec 2009)



# Growth Of $CO_2$ Plume? (13 Jan 2010)



# Cross Well ERT (2-23-10)




Resistive plume = CO2 in reservoir

Conductive plume= workover fluids?

Charles Carrigan, LLNL

# SECARB Phase III

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**Anthropogenic Test**

Capture: Alabama Power Plant Barry, Bucks, Alabama

Transportation: Denbury Resources

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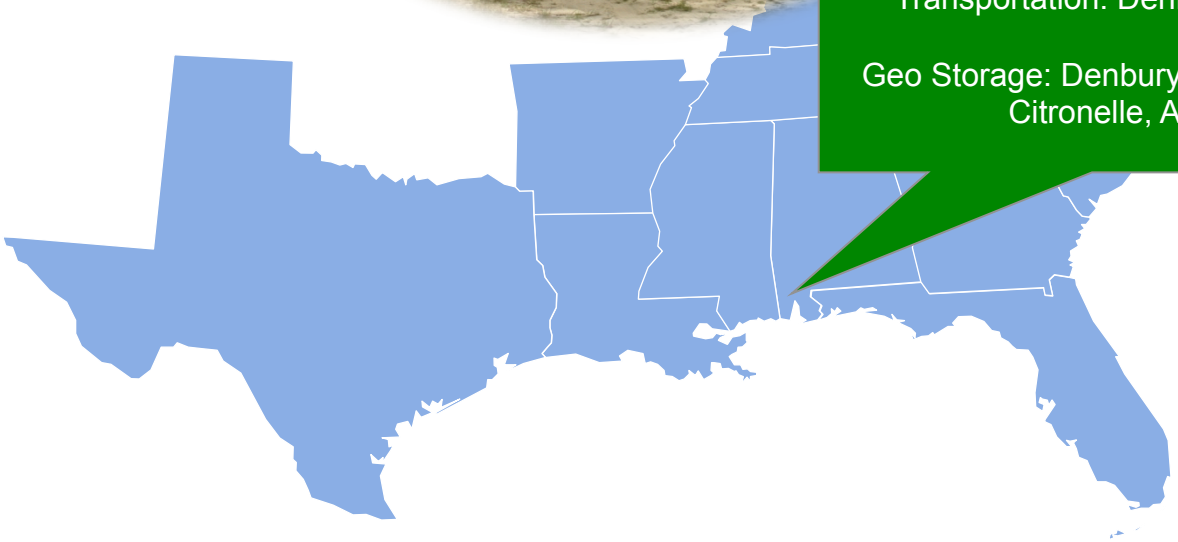
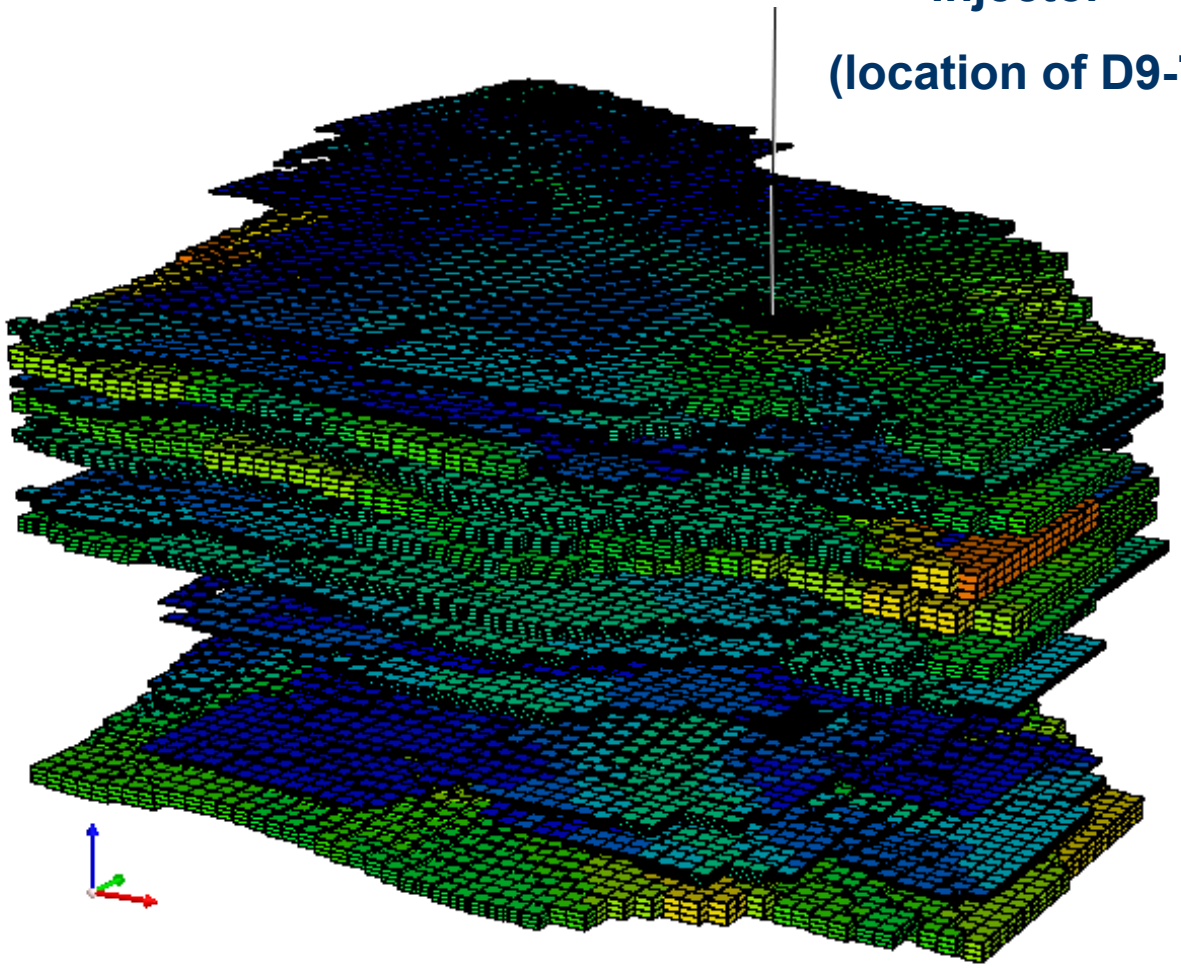


# Expected Reservoir Intersection Depths at Citronelle

| Formation Tops | Anticipated Depth Feet | Interval Thickness Feet |
|---|---|---|
| Bottom of Fresh Water (<1,000 mg/l) | ~ 1,000 | 1,000 |
| Bottom of Potable Water (<10,000 mg/l) | Max ~ 2,000 | 1,000 |
| Selma Chalk Group | 4,550 | 1,150 |
| Eutaw Group | 5,700 | 300 |
| Upper Tuscaloosa Formation | 6,000 | 700 |
| Marine Tuscaloosa Formation | 6,700 | 250 |
| Lower Tuscaloosa Formation | 6,950 | 300 |
| Washita-Fredericksburg Undifferentiated | 7,250 | 2,150 |
| **Paluxy Formation** | **9,400** | **1,100** |
| Mooringsport Formation | 10,500 | 250 |
| Ferry Lake Anhydrite | 10,750 | 200 |
| Rodessa Formation (oil reservoir) | 10,950 | - |

# Model 3-D View of  Citronelle Injection Site




- 17 sand bodies from geological model
- Average permeability of 88 mD
- Average porosity of 19.3%
- Identical permeability and porosity in all layers

# Capture Unit at Alabama Power's Plant Barry

SECARB
Southeast Regional Carbon Sequestration Partnership

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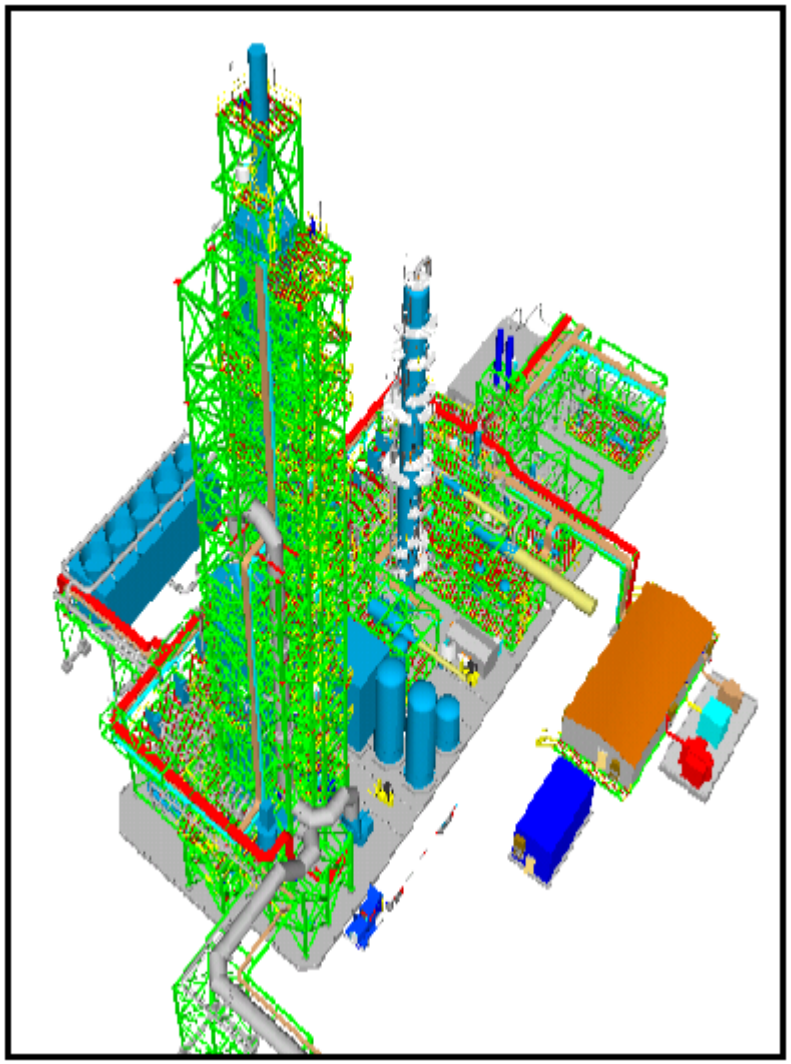
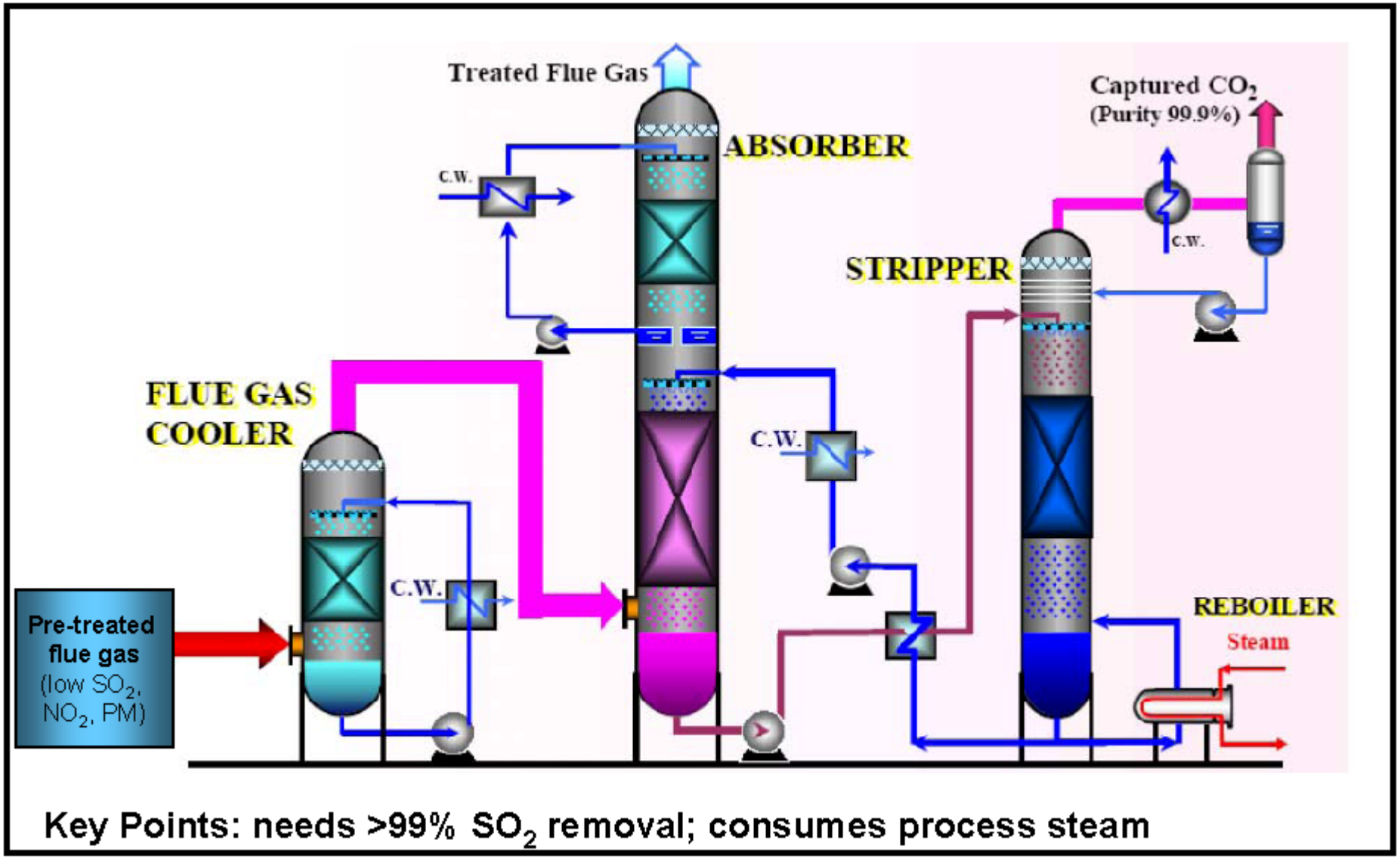
**MHI advanced amine capture unit**

- 25 MW post combustion slip stream
- Fabricate off-site and barge to Plant Barry
- Compress $CO_2$ to 2000 psi
- Scheduled start up during summer, 2011
- Separately funded



# Simplified $CO_2$ Scrubbing Process (Amine)




Key Points: needs >99% $SO_2$ removal; consumes process steam

# Groundbreaking Ceremony: Capture Unit

Alabama Power's Plant Barry, April 14, 2010, Bucks, Alabama


SOUTHERN COMPANY

MITSUBISHI HEAVY INDUSTRIES, LTD.

EPRI ELECTRIC POWER RESEARCH INSTITUTE

# Site Progress Photos (10-8-10)

# Integration Questions

- What business relationships must be established among the $CO_2$ provider, transporter and injection field operator?
- How can a $CO_2$ transportation and injection system impact plant operations and scheduling?
- How can cycling a plant on-line and off-line impact $CO_2$ transportation and injection?
- What types of communications and control systems are needed to support integration?
- How can lessons learned assist in scale up?

# Phase III Findings – to date

- CO2 Enhanced Oil Recovery (EOR) provides an economic offset for CCS “first movers”
- EOR and saline storage potential in the Southern region is highest in the nation
- Integration of capture, transportation, storage and monitoring systems presents a business challenge to the industry
- Reliable monitoring, measurement and verification tools have been demonstrated for EOR and saline storage